

INDOOR AIR QUALITY ASSESSMENT

**Littleton Middle School
55 Russell Street
Littleton, Massachusetts**



Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
August 2005

Background/Introduction

At the request of parents, the Massachusetts Department of Public Health's (MDPH), Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality concerns at the Littleton Middle School (LMS), 55 Russell Street, Littleton, Massachusetts. Concerns related to chronic roof leaks and water infiltration prompted the request.

On March 30, 2005, a visit to conduct an indoor air quality assessment was made to this building by Cory Holmes, Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Ira Grossman of the Nashoba Associated Boards of Health, Bill Mahar, Director of Maintenance, Littleton Public Schools (LPS) and Kevin Moran, LMS Principal, accompanied Mr. Holmes during the assessment.

The LMS is a one-story brick building on slab that was constructed in the 1950's. The school contains general classrooms, science rooms, a gymnasium, locker rooms, music rooms, art room, library, computer lab, kitchen/cafeteria and office space. The boiler plant is located in the basement and is accessible from both an exterior and interior stairwell. At the time of the assessment, construction of a new middle school adjacent to the existing building was planned for the summer of 2005. The existing building will be demolished upon completion of the new LMS. The gymnasium for the new LMS will be rebuilt on the existing framework of the current gymnasium. School officials reported that the new school was tentatively scheduled for completion for the 2006-2007 school year.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). MDPH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The building has a sixth through eighth grade student population of approximately 355 and a staff of approximately 30. Tests within the building were taken under normal operating conditions. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million of air (ppm) in all areas surveyed throughout the building, indicating adequate air exchange. However, some areas were empty or sparsely populated and windows and exterior doors were open in several areas at the time of the assessment. Low occupancy and open windows/exterior doors can greatly reduce carbon dioxide levels. Therefore, carbon dioxide levels would be expected to be higher with increased occupancy and windows/doors shut.

Air handling units (AHUs) located in the boiler room provide fresh air to classrooms (Picture 1). Fresh air is drawn through intakes on exterior walls (Picture 2), ducted through the slab and supplied to occupied spaces by wall-mounted diffusers (Picture 3). Air is ducted back to the AHUs through return vents installed in the floor (Picture 4). These systems were operating during the assessment.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration

(OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see [Appendix A](#).

Temperature readings were measured in a range of 69° F to 77° F, which were very close to the MDPH recommended comfort range. The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 24 to 34 percent, which were below the MDPH recommended comfort range in all areas surveyed. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. During the heating season, relative humidity levels would be expected to drop below the recommended comfort range. The sensation of dryness and irritation is common in a low relative humidity environment. For buildings in New England, periods of low relative humidity during the winter are often unavoidable.

Microbial/Moisture Concerns

The building has a history of chronic roof leaks, despite efforts to replace sections or patch areas over the years (Pictures 5 and 6). Active roof leaks were observed in several areas during the assessment. In an effort to collect water, buckets, barrels and other reservoirs were in use throughout the building (Picture 7). Current and historic roof leaks are a result of pooling water on the roof (Pictures 8 and 9). MDPH staff examined the roof and found the roof surface to be rippled and bulging in various areas (Picture 9).

Missing and/or water-damaged ceiling tiles and other building materials were observed throughout the building (Pictures 10 through 12). Water-damaged porous building materials (e.g., ceiling tiles) can provide a source of mold growth and should be replaced after a water leak is discovered and repaired.

Another major pathway for water penetration into the building included damage to exterior walls and doors. Evidence of severe water penetration into the subterranean boiler room was observed (Pictures 13 through 16). Portions of the basement are used for storage. Because of standing water, some of the stored items were moistened. Porous materials that can support mold growth, such as wooden pallets, cardboard, paper and other items appeared to be colonized with mold (Pictures 17 through 19). The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

Potential means for the movement of musty odors and particulates from the boiler room to enter occupied areas of the building were identified. The most obvious pathway was through breaches in ductwork (Picture 20). At the time of the assessment, measures to prevent chronic water penetration into the boiler room were not feasible; however, MDPH staff recommended the removal of all water-damaged materials from the boiler room as well as the sealing of breaches in ductwork to avoid entrainment of odors and particulates into the ventilation system.

Other potential pathways for moisture to enter into the building include open holes (Picture 21), missing/damaged mortar on exterior walls (Picture 22) and missing/damaged caulking around window and door frames (Pictures 23 through 25). These breaches to the building envelope can allow water to penetrate the building. Repeated water penetration can result in the chronic wetting of building materials and potential microbial growth. In addition, these holes may provide a means of egress for pests/rodents into the building.

The building is equipped with gutters and downspouts to drain rainwater away from the building. Several downspouts were missing elbows, causing water to empty and pool against the foundation (Picture 26). Excessive exposure of exterior brickwork to water can result in damage over time. During winter weather, the freezing and thawing of moisture in bricks can accelerate the deterioration of brickwork, which can lead to water intrusion.

Several areas had a number of plants. Moistened plant soil and drip pans can be a source of mold growth (Picture 27). Of particular note was a large indoor planter in the main lobby (Picture 28). This large indoor planter is constructed of brick and did not appear to have a means for drainage. Plants are also a source of pollen. Over watering of plants should

be avoided. Plants should be located away from the air stream of ventilation sources to prevent the aerosolization of mold, pollen or particulate matter throughout the classroom.

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM_{2.5}) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM_{2.5}.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC

systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). Carbon monoxide levels measured inside the school were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM₁₀). According to the NAAQS, PM₁₀ levels should not exceed 150 microgram per cubic meter ($\mu\text{g}/\text{m}^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent PM_{2.5} standard requires outdoor air particle levels be maintained below 65 $\mu\text{g}/\text{m}^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM₁₀ standard for evaluating air quality, MDPH uses the more

protective proposed PM_{2.5} standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM_{2.5} concentrations were measured at 11 µg/m³ (Table 1). PM_{2.5} levels measured in the school were between 8 to 17 µg/m³, which were slightly above outdoor measurements in some but below the NAAQS of 65 µg/m³ in all areas (Table 1). Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC concentrations were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. In an effort to identify materials that can

potentially increase indoor TVOC concentrations, MDPH staff examined classrooms for products containing these respiratory irritants. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellulose (Sanford, 1999), which can be irritating to the eyes, nose and throat.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs (Picture 29). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and cause TVOCs to off-gas. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as [Appendix B](#) (NIOSH, 1998).

Supply diffusers, return vents and fan blades to personal fans were occluded with dust (Picture 30). Reactivated fans and AHUs can serve to distribute accumulated dust. If exhaust vents become deactivated, backdrafting can result in the re-aerosolization of accumulated dust particles. Dust can be irritating to the eyes, nose and respiratory tract. Flat surfaces should be wet wiped and cleaned with a vacuum equipped with the high efficiency particulate arrestance (HEPA) filter on a regular basis.

Conclusions/Recommendations

The conditions present within the LMS require three distinct remediation activities: A) removal/cleaning of stored materials in the basement, B) remediation to reduce/prevent water sources from entering the building, and C) general indoor air quality recommendations. As discussed, at the time of the assessment, replacement of the LMS was approved by the Town of Littleton, with a tentative completion date of winter 2006-2007. In the interim, students and faculty will return to the existing building, therefore the following recommendations are made to improve indoor air quality conditions.

A) Removal/Cleaning of Water Damaged Basement Materials

1. *Ensure that the general mechanical ventilation system is **deactivated** and that any openings (e.g., vents, breaches) are sealed during remediation.* Discard stored materials and building materials that appear to have mold contamination. This measure will remove actively growing mold colonies that may be present. Remove mold contaminated materials in a manner consistent with recommendations in “Mold Remediation in Schools and Commercial Buildings” published by the US Environmental Protection Agency (US EPA, 2001). Copies of this document can be downloaded from the US EPA website at:
http://www.epa.gov/iaq/molds/mold_remediation.html.
2. Seal the boiler room off from the stairwell with a temporary impermeable barrier (e.g., plastic sheeting, wood) as part of remediation activities. Ensure barrier is as airtight as possible by sealing edges and frames duct tape. Inspect for drafts and/or light penetration to ensure airtight integrity.

3. Use local exhaust ventilation and isolation techniques to control remediation pollutants. Precautions should be taken to avoid the re-entrainment of these materials into the building.
4. Disinfect non-porous surfaces (e.g., floors, walls, metal) with a one-in-ten bleach solution.
5. Establish communications between all parties involved with remediation efforts, including building occupants, to prevent potential IAQ problems.
6. Develop a notification system for building occupants to report remediation related odors and/or issues to the building administrator. Have these concerns relayed to the contractor and/or contact person in a manner that allows for a timely remediation of the problem.

B) Water Infiltration Recommendations

1. Ensure LPS maintenance staff continue to monitor for active leaks, considering current conditions of the roof. School occupants should continue to notify the main office if leaks are observed for prompt action.
2. Continue working with roofing contractor in making roof repairs/patches as needed to prevent further water penetration.
3. Empty buckets used to collect leaks regularly to prevent standing water, mold growth and associated odors. Clean and disinfect buckets and surface areas around leaks with an appropriate anti-microbial as needed.
4. Repair/replace exterior doors to boiler room to prevent/reduce water infiltration.

5. Repair/replace broken windows; re-seal loose window frames to prevent drafts and water penetration. Seal hole in window in science wing.
6. Install elbow extensions on downspouts to direct rain water away from the building.
7. Contact a masonry firm or general contractor to repair holes/breaches in exterior walls/joints to prevent water penetration, drafts and pest entry.

C) General Air Quality Recommendations

1. Operate all ventilation systems throughout the building (e.g., gym, auditorium, classrooms) continuously during periods of school occupancy independent of thermostat control to maximize air exchange.
2. Continue to change filters for air handling equipment as per manufacturer's instructions, or more frequently if needed.
3. Use windows to supplement the introduction of fresh air. Open windows on both sides of the building to provide cross ventilation.
4. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, use a HEPA filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

5. Replace/remove severely water-damaged ceiling tiles. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
6. Ensure all plants are equipped with drip pans. Avoid over watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary. Move plants away from ventilation sources in classrooms.
7. Clean air diffusers, exhaust/return vents and personal fan blades periodically of accumulated dust.
8. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.
9. Consider adopting the US EPA (2000b) document, “Tools for Schools” to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at <http://www.epa.gov/iaq/schools/index.html>.
10. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH’s website at <http://www.state.ma.us/dph/beha/iaq/iaqhome.htm>.

References

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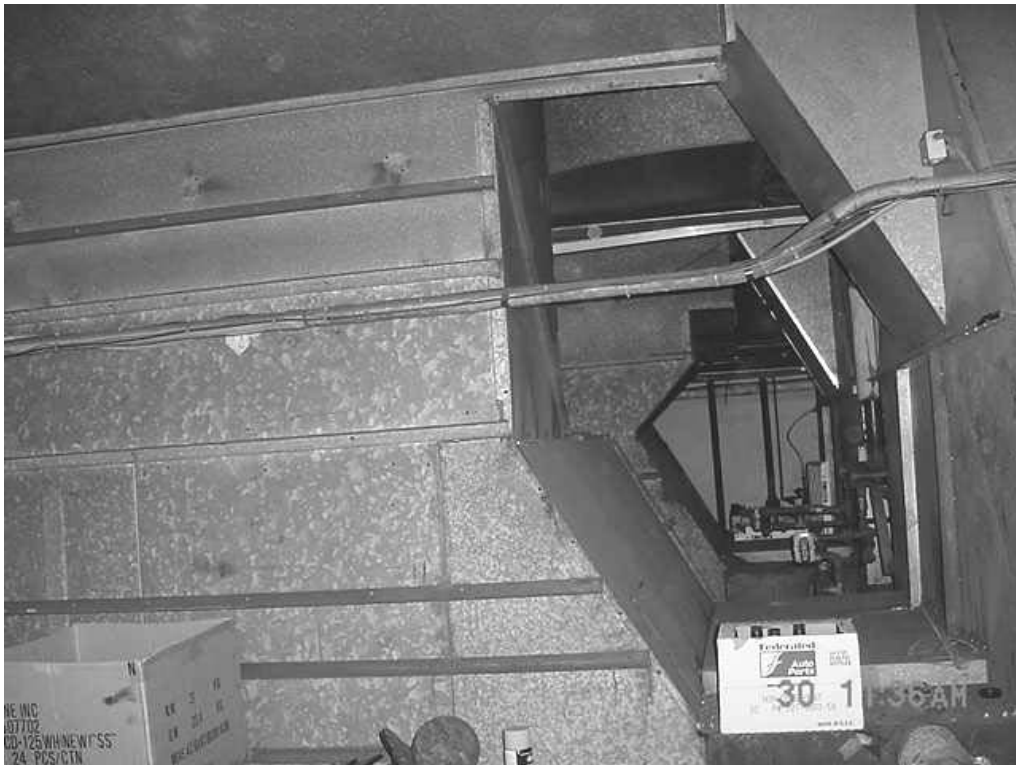
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Picture 1



Ducted Air Handling Units in Boiler Room

Picture 2



Fresh Air Intake Vent

Picture 3



Wall-Mounted Supply Vents along Window Frames

Picture 4



Floor Return Vent

Picture 5



Large Roof Patch

Picture 6



Small Roof Patches

Pictures 7



Barrel and Bucket Stationed to Catch Roof Leaks

Picture 8



Water Pooling on Roof

Picture 9



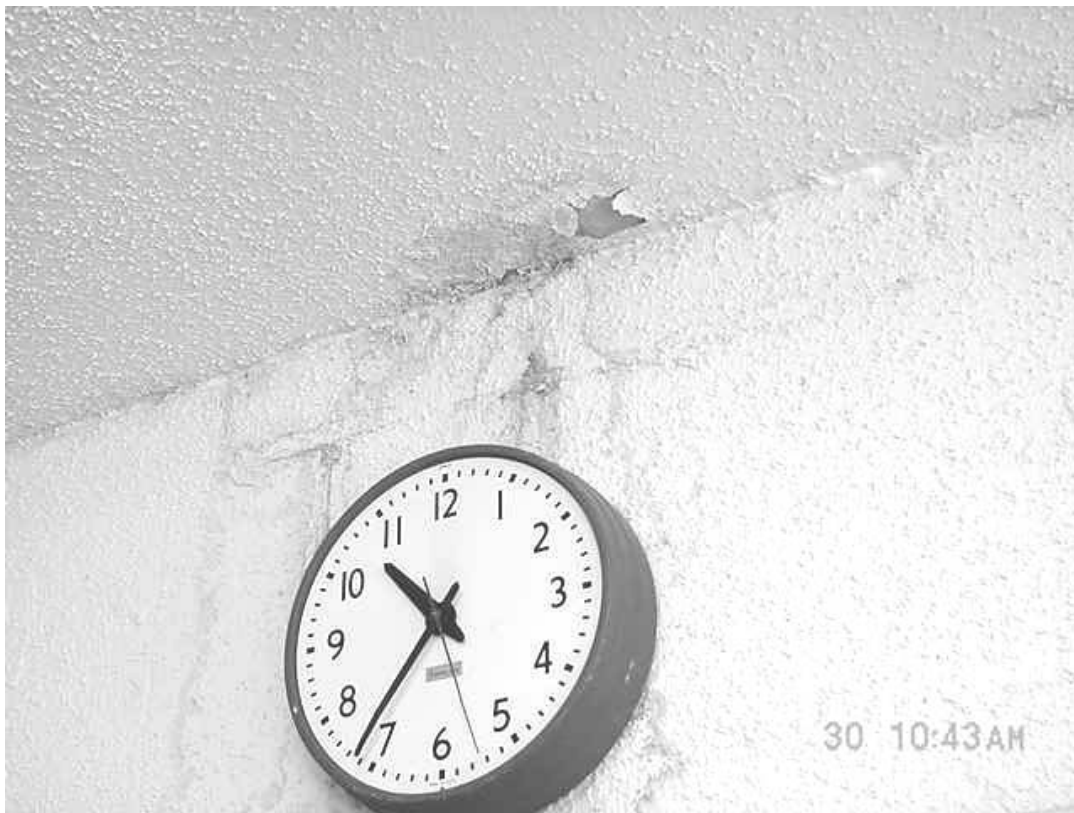
Water Pooling on Roof, Note Uneven Surface and “Raised” Areas

Picture 10



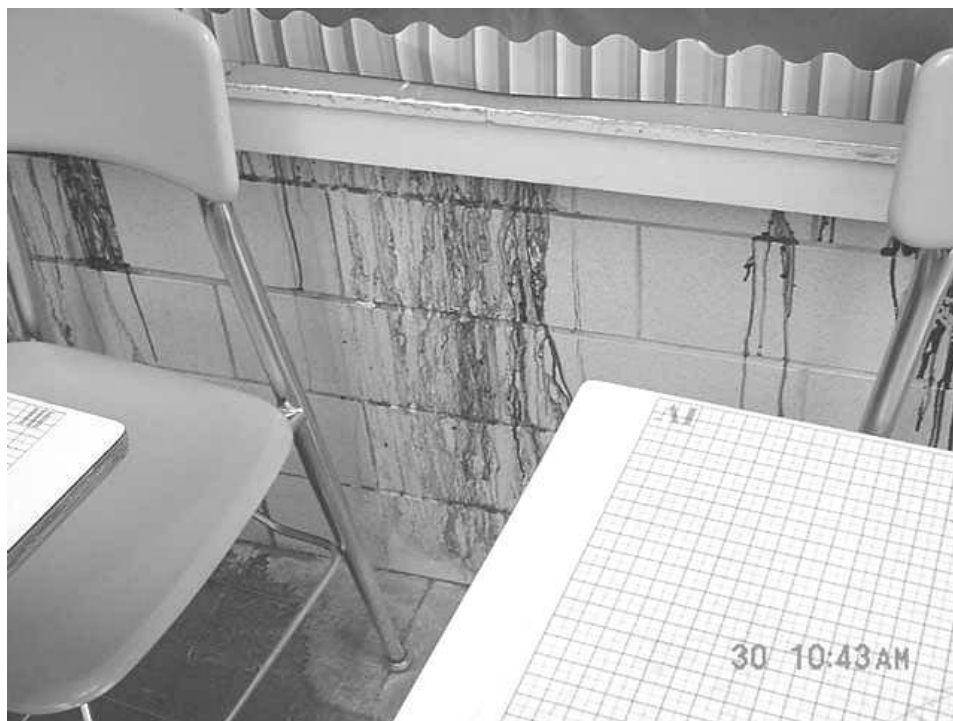
Missing/Water Damaged Ceiling Tiles in Library

Picture 11



Water Damaged Ceiling/Wall Plaster

Picture 12



Water Staining on Wall

Picture 13



Water Penetration through Exterior Door and Down Stairs into the Boiler Room

Picture 14



Exterior View of Boiler Room Door

Picture 15



Water Penetration down Stairs into Boiler Room

Picture 16



Water Penetration down Foundation Wall of Boiler Room

Picture 17



Water Damaged/Mold Colonized Porous Materials Stored in the Boiler Room

Picture 18



Water Damaged/Mold Colonized Wooden Pallets Stored in the Boiler Room

Picture 19



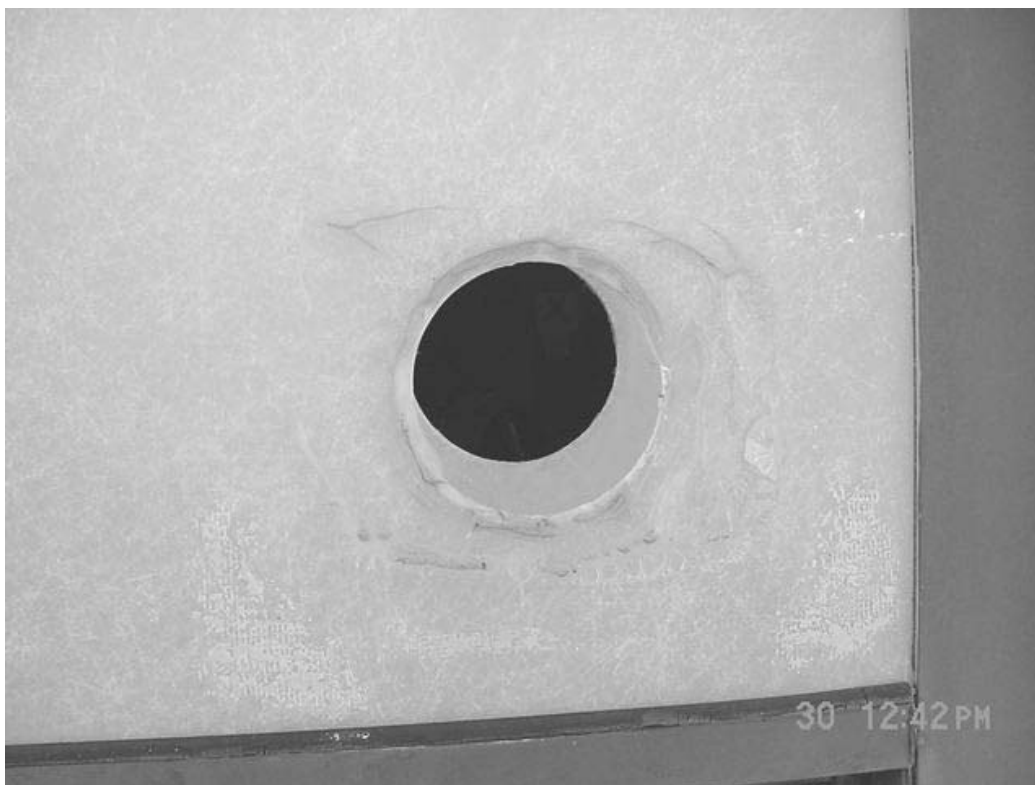
Water Damaged/Mold Colonized Plywood and Debris in the Boiler Room

Picture 20



Breach in Ductwork (Boiler Room)

Picture 21



Open Hole in Plexiglas Window, Science Wing (Reportedly for Flammables Cabinet)

Picture 22



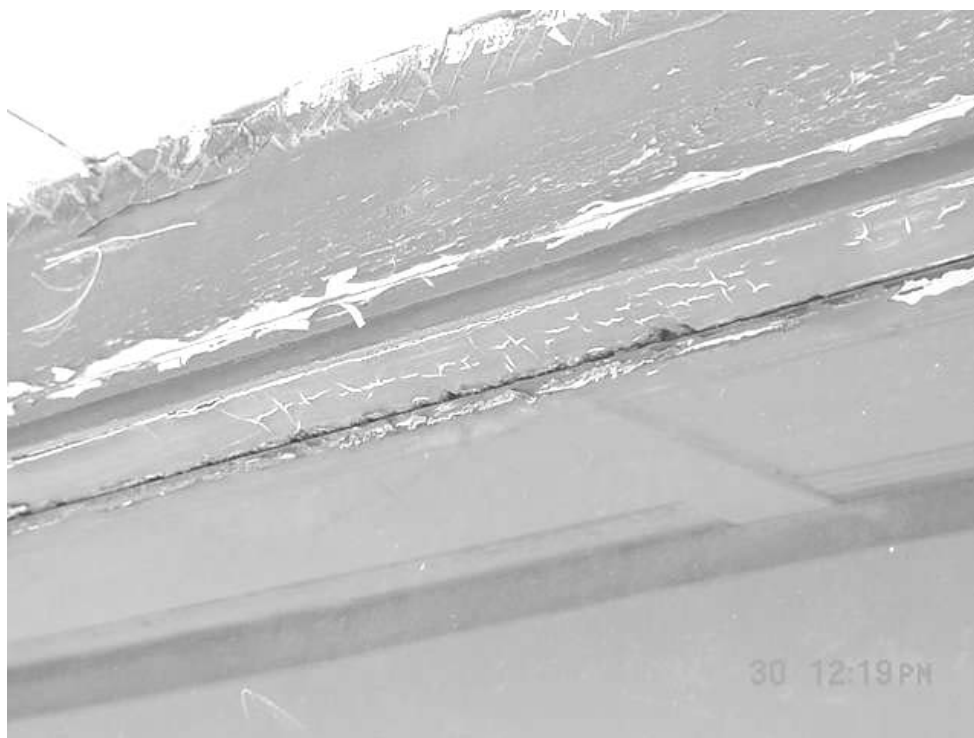
Missing/Damaged Mortar around Exterior Brick

Picture 23



Missing/Damaged Caulking around Window Panes

Picture 24



Missing/Damaged Caulking around Window Panes

Picture 25



Missing/Damaged Caulking around Door Frame

Picture 26



Downspout Missing Elbow Extension

Picture 27



Plant with Standing Water in Pot

Picture 28



Large Indoor Planter in Main Lobby

Picture 29



Tennis Ball on Chair Leg

Picture 30



Dust and Debris Occluding Floor (Return) Vents

Littleton Middle School
55 Russell Street, Littleton, MA

Indoor Air Results
March 30, 2005

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background	0	60	33	388	ND	ND	11				mostly sunny, warm.
9	21	73	31	672	ND	ND	11	Y # open: 0 # total: 2	Y wall	Y floor	WD-ceiling, DEM, PF, cleaners, active roof leaks-buckets.
10	22	75	33	713	ND	ND	10	Y # open: 0 # total: 2	Y wall	Y floor	WD-ceiling, DEM, PF, active roof leaks-buckets.
19	25	76	30	735	ND	ND	17	Y # open: 2 # total: 2	Y wall	Y floor	Hallway DO, DEM.
Library	1	71	25	454	ND	ND	10	Y # open: 0 # total: 3	Y wall	Y floor	Hallway DO, WD-ceiling, #WD-CT: 4, #MT/AT: 4.

ppm = parts per million

µg/m3 = micrograms per cubic meter

AD = air deodorizer

AP = air purifier

aqua. = aquarium

AT = ajar ceiling tile

BD = backdraft

CD = chalk dust

CP = ceiling plaster

CT = ceiling tile

DEM = dry erase materials

design = proximity to door

FC = food container

G = gravity

GW = gypsum wallboard

M = mechanical

MT = missing ceiling tile

NC = non-carpeted

ND = non detect

PC = photocopier

PF = personal fan

plug-in = plug-in air freshener

PS = pencil shavings

sci. chem. = science chemicals

TB = tennis balls

terra. = terrarium

UF = upholstered furniture

WD = water damage

WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Table 1-1

Littleton Middle School
55 Russell Street, Littleton, MA

Indoor Air Results
March 30, 2005

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
11	0	76	31	619	ND	ND	9	Y # open: 1 # total: 2	Y wall	Y floor	DEM.
17	1	77	29	618	ND	ND	9	Y # open: 1 # total: 2	Y wall items	Y wall dust/debris	Hallway DO, DEM, 19 occupants gone 22 min.
Cafeteria	100	73	28	789	ND	ND	10	Y # open: 2 # total: 2	Y wall	Y floor	Hallway DO,
Boy's Locker Room	0	72	30	537	ND	ND	8	Y # open: 0 # total: 0	Y wall	Y ceiling	
Girl's Locker Room	0	71	29	524	ND	ND	9	Y # open: 0 # total: 0	Y wall	Y ceiling	

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Comfort Guidelines

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Table 1-2

Littleton Middle School
55 Russell Street, Littleton, MA

Indoor Air Results
March 30, 2005

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Gym	0	69	34	519	ND	ND	8	Y # open: 0 # total: 12	Y wall	Y wall	Hallway DO, WD-ceiling.
Auditorium	0	72	24	453	ND	ND	11	N # open: 0 # total: 0	Y wall	Y wall	
1	24	73	28	702	ND	ND	10	Y # open: 1 # total: 2	Y wall	Y floor	Hallway DO, TB.
3	26	74	27	710	ND	ND	10	Y # open: 0 # total: 2	Y wall	Y floor	WD-ceiling, DEM, TB.
20	1	75	28	523	ND	ND	8	Y # open: 0 # total: 4	Y wall	Y wall	window-mounted AC,

ppm = parts per million

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design = proximity to door

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G = gravity

GW = gypsum wallboard

M = mechanical

MT = missing ceiling tile

NC = non-carpeted

ND = non detect

PC = photocopier

PF = personal fan

plug-in = plug-in air freshener

PS = pencil shavings

sci. chem. = science chemicals

TB = tennis balls

terra. = terrarium

UF = upholstered furniture

WD = water damage

WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Table 1-3